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OKAUCHEE LAKE, WAUKESHA COUNTY, WISCONSIN

Pacific Northwest Environmental Research Laboratory

Prepared for:

National Environmental Research Center
Wisconsin Department of Natural Resources
Wisconsin National Guard

June 1975

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U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

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PACIFIC NORTHWEST ENVIRONMENTAL RESEARCH LABORATORY

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT
ON
OKAUCHEE LAKE
WAUKESHA COUNTY
WISCONSIN

EPA REGION V

WORKING PAPER No. 64

WITH THE COOPERATION OF THE

WISCONSIN DEPARTMENT OF NATURAL RESOURCES

AND THE

WISCONSIN NATIONAL GUARD

JUNE, 1975

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS*

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

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* The lake discussed in this report was included in the National Eutrophication Survey as a water body of interest to the Wisconsin Department of Natural Resources. Nutrient sources were not sampled, and this report relates only to the data obtained from lake sampling.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Wisconsin Department of Natural Resources for professional involvement and to the Wisconsin National Guard for conduct of the tributary sampling phase of the Survey.

Francis H. Schraufnagel, Acting Assistant Director, and Joseph R. Ball of the Bureau of Water Quality, and Donald R. Winter, Lake Rehabilitation Program, provided invaluable lake documentation and counsel during the Survey. Central Office and District Office personnel of the Department of Natural Resources reviewed the preliminary reports and provided critiques most useful in the preparation of this Working Paper series.

Major General James J. Lison, Jr., the Adjutant General of Wisconsin, and Project Officer CW-4 Donald D. Erickson, who directed the volunteer efforts of the Wisconsin National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

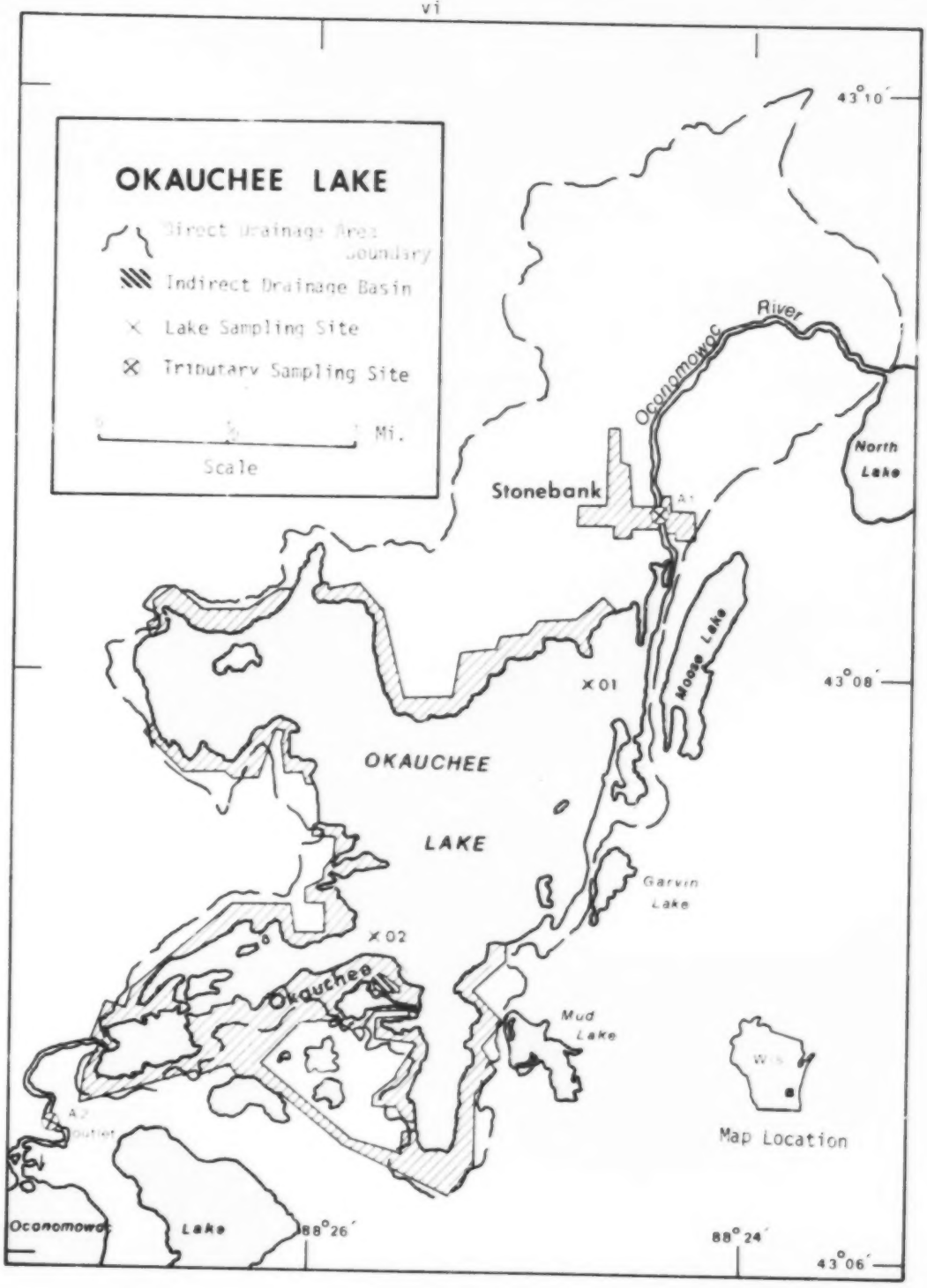
NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF WISCONSIN

LAKE NAME	COUNTY
Altoona	Eau Claire
Beaver Dam	Barron
Beaver Dam	Dodge
Big Eau Pleine	Marathon
Browns	Racine
Butte des Morts	Winnebago
Butternut	Price, Ashland
Castle Rock Flowage	Juneau
Como	Walworth
Crystal	Vilas
Delavan	Walworth
Eau Claire	Eau Claire
Geneva	Walworth
Grand	Green Lake
Green	Green Lake
Kegonsa	Dane
Koshkonong	Jefferson, Rock, Dane
Lac La Belle	Waukesha
Middle	Walworth
Nagawicka	Waukesha
Oconomowoc	Waukesha
Okauchee	Waukesha
Petenwell Flowage	Juneau
Pewaukee	Waukesha
Pigeon	Waupaca
Pine	Waukesha
Poygan	Winnebago, Waushara
Rock	Jefferson
Rome Pond	Jefferson, Waukesha
Round	Waupaca
Shawano	Shawano

LAKE NAME	COUNTY
Sinnissippi	Dodge
Swan	Columbia
Tainter	Dunn
Tichigan	Racine
Townline	Oneida
Trout	Vilas
Wapogassett	Polk
Wausau	Marathon
Willow	Oneida
Winnebago	Winnebago, Fond Du Lac, Calumet
Wisconsin	Columbia
Wissota	Chippewa
Yellow	Burnett


OKAUCHEE LAKE
Direct Drainage Area Boundary
Indirect Drainage Basin
Lake Sampling Site
Tributary Sampling Site
Mi.
Scale
43°10′
Oconomowoc River
North Lake
Stonebank
A1
Moose Lake
43°08′
X01
OKAUCHEE
LAKE
Garvin Lake
X02
Okauchee
Mud Lake
Map Location
A2
Outlet
Oconomowoc
Lake
88°26′
88°24′
43°06′

OKAUCHEE LAKE

STORET NO. 5558

I. INTRODUCTION

Okauchee Lake was included in the National Eutrophication Survey as a water body of interest to the Wisconsin Department of Natural Resources. The inlet and outlet of the lake were sampled (Appendix C), but no wastewater treatment plants impact the lake. Therefore, this report relates only to the lake sampling data.

II. CONCLUSIONS

A. Trophic Condition:

Survey data and a report by others (Poff and Threinen, 1963) indicate Okauchee Lake is in an early eutrophic condition. Of the 46 Wisconsin lakes sampled, six had less mean total phosphorus, four had less and one had the same mean dissolved phosphorus, 21 had less mean inorganic nitrogen, 13 had greater mean Secchi disc transparency, and 20 lakes had less mean chlorophyll a. Depression of dissolved oxygen with depth (37 feet and deeper) occurred at station 2 in August and at 74 feet in November.

Submerged aquatic vegetation is a major use-problem (Poff and Threinen, 1963), and the lake has received chemical treatment for the control of both weeds and algae for a number of years (Lueschow, 1972).

B. Rate-Limiting Nutrient:

The algal assay results indicate Okauchee Lake was phosphorus limited at the time the sample was taken (11/11/72). The lake data indicate phosphorus limitation in August as well but nitrogen limitation in June.

III. LAKE AND DRAINAGE BASIN CHARACTERISTICS

A. Lake Morphometry†:

1. Surface area: 1,104 acres.
2. Mean depth: 29.6 feet.
3. Maximum depth: 90 feet.
4. Volume: 32,688 acre-feet.
5. Mean hydraulic retention time: 300 days.

B. Tributary and Outlet:
(See Appendix A for flow data)

1. Tributaries -

Name	Drainage area (mi^2)*	Mean flow (cfs)*
Oconomowoc River	74.3	48.5
Minor tributaries & immediate drainage -	7.8	6.5
Totals	82.1	55.0

2. Outlet -

Oconomowoc River	83.8**	55.0**

C. Precipitation***:

1. Year of sampling: 38.7 inches.
2. Mean annual: 30.7 inches.

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† WI Dept. Cons. lake survey map (1955).
* Drainage areas are accurate within ±0.5%; mean daily flows are accurate within ±40%; mean monthly flows are accurate within ±35%; and normalized monthly flows are accurate within ±35%.
** Includes area of lake; outflow adjusted to equal sum of inflows.
*** See Working Paper No. 1, "Survey Methods, 1972".

IV. LAKE WATER QUALITY SUMMARY

Okauchee Lake was sampled three times during the open-water season of 1972 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from two stations on the lake and usually from a number of depths at each station (see map, page vi). During each visit, a single depth-integrated (15 feet or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the last visit, a single five-gallon depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths samples were 31 feet at station 1 and 77 feet at station 2.

The results obtained are presented in full in Appendix B, and the data for the fall sampling period, when the lake essentially was well-mixed, are summarized below. Note, however, the Secchi disc summary is based on all values.

For differences in the various parameters at the other sampling times, refer to Appendix B.

A. Physical and chemical characteristics:

Parameter	Minimum	Mean	Median	Maximum
		FALL VALUES		
Temperature (Cent.)	6.6	7.2	7.1	7.4
Dissolved oxygen (mg/l)	2.1	8.3	8.9	9.2
Conductivity (μmhos)	485	488	490	495
pH (units)	7.5	7.8	7.8	7.8
Alaklinity (mg/l)	188	202	201	214
Total P (mg/l)	0.015	0.018	0.016	0.033
Dissolved P (mg/l)	0.008	0.010	0.009	0.016
$NO_2 + NO_3$ (mg/l)	0.140	0.206	0.220	0.250
Ammonia (mg/l)	0.100	0.117	0.100	0.270
		ALL VALUES		
Secchi disc (inches)	12	75	72	113

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Number per ml
06/21/72	1. Fragilaria	796
	2. Dinobryon	413
	3. Stephanodiscus	199
	4. Microcystis	127
	5. Anabaena	121
	Other genera	399
	Total	2,055
08/19/72	1. Chroococcus	355
	2. Dinobryon	347
	3. Merismopedia	239
	4. Synura	232
	5. Oocystis	224
	6. Fragilaria	224
	Other genera	861
	Total	2,482
11/11/72	1. Fragilaria	298
	2. Anabaena	293
	3. Dinobryon	195
	4. Asterionella	166
	5. Microcystis	119
	Other genera	347
	Total	1,418

2. Chlorophyll a -
(Because of instrumentation problems during the 1972 sampling, the following values may be in error by plus or minus 20 percent.)

Sampling Date	Station Number	Chlorophyll a (μg/l)
06/21/72	01	12.7
	02	14.9
08/19/72	01	4.0
	02	4.1
11/11/72	01	7.7
	02	6.7

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.014	0.319	3.5
0.006 P	0.020	0.319	6.2
0.012 P	0.026	0.319	7.7
0.024 P	0.038	0.319	8.4
0.060 P	0.074	0.319	9.2
0.060 P + 10.0 N	0.074	10.319	29.6
10.0 N	0.014	10.319	3.8

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity of Okauchee Lake was relatively high at the time the sample was taken (11/11/72). Also, the results indicate that phosphorus was the growth-limiting nutrient. Note that the addition of orthophosphorus resulted in increases in growth

of the test alga, but there was not significant growth response to the addition of nitrogen alone.

If all lake data are used, including the high nitrogen values below 22 feet at station 2, phosphorus limitation would be indicated at all sampling times. However, if only values from the photic zone (assumed to be from the surface to 22 feet) are used, the lake data indicate nitrogen limitation in June (N/P = 8/1) and phosphorus limitation in August (N/P = 19/1) and November (N/P = 18/1).

V. LITERATURE REVIEWED

Lueschow, Lloyd A., 1972. Biology and control of selected aquatic nuisances in recreational waters. Tech. Bull. No. 57, WI Dept. Nat. Resources, Madison.

McKersie, Jerome, George Hansel, Floyd Stautz, and Dick Narf; 1969. Report on an investigation of the pollution in the upper Rock River drainage basin made during 1967-1968. WI Dept. Nat. Resources, Madison.

Poff, Ronald J., and C. W. Threinen, 1963. Surface water resources of Waukesha County. WI Cons. Dept., Madison.

V. APPENDICES

APPENDIX A

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR WISCONSIN 9/30/74

LAKE CODE 5558 OCKAUCHEE LAKE

TOTAL DRAINAGE AREA OF LAKE 83.80

TRIBUTARY	SUB-DRAINAGE AREA	NORMALIZED FLOWS JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
5558A1	74.30	27.00	32.00	85.00	110.00	64.00	74.00	34.00	24.00	31.00	31.00	44.00	26.00	48.46
5558A2	83.80	31.20	35.10	93.60	126.70	72.10	85.80	39.05	27.20	35.10	36.10	49.70	30.20	55.10
5558ZZ	9.50	3.60	4.00	11.00	14.00	8.40	10.00	4.50	3.20	4.00	5.80	5.80	3.50	6.48

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 83.80 TOTAL FLOW IN = 659.80
SUM OF SUB-DRAINAGE AREAS = 83.80 TOTAL FLOW OUT = 661.80

MEAN MONTHLY FLOWS AND DAILY FLOWS

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
5558A1	9	72	110.00	23	180.00				
	10	72	130.00						
	11	72	99.00						
	12	72	38.00	9	32.00				
	1	73	77.00						
	2	73	56.00	11	56.00				
	3	73	130.00	18	180.00				
	4	73	340.00	14	230.00	29	210.00		
	5	73	220.00	22	160.00	26	180.00		
	6	73	87.00	16	78.00				
	7	73	24.00	1	36.00				
	8	73	16.00	26	17.00				
5558A2	9	72	130.00	23	200.00				
	10	72	150.00						
	11	72	110.00						
	12	72	43.00	9	35.00				
	1	73	89.00						
	2	73	67.00	11	67.00				
	3	73	150.00	18	210.00				
	4	73	380.00	14	250.00	29	230.00		
	5	73	250.00	22	180.00	26	200.00		
	6	73	98.00	16	92.00				
	7	73	27.00	1	40.00				
	8	73	18.00	26	19.00				
5558ZZ	9	72	18.00	23	27.00				
	10	72	20.00						
	11	72	15.00						
	12	72	5.80	9	4.80				
	1	73	6.00						
	2	73	3.20	11	3.20				
	3	73	11.00	18	14.00				
	4	73	76.00	14	52.00	29	34.00		
	5	73	36.00	22	26.00	26	24.00		
	6	73	9.50	16	9.00				
	7	73	4.30	1	6.40				
	8	73	3.00	26	3.00				

APPENDIX B

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 74/09/30

555801
43 07 54.0 088 04 48.0
OKAUCHEE LAKE
55 WISCONSIN

11EPALES 2111202
3 000A FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/21	13 50	0000	15.9	10.0	72	385	8.50	187	0.020	0.030	0.022	0.009
72/08/19	14 10	0000			12	410	8.41	169	0.060	0.090	0.015	0.008
	14 10	0004	26.2	9.8		408	8.45	166	0.070	0.080	0.012	0.007
	14 10	0009	24.0	10.6		410	8.40	166	0.060	0.070	0.018	0.007
72/11/11	10 30	0000			113	490	7.80	210	0.250	0.110	0.016	0.008
	10 30	0004	7.1	9.2		490	7.80	210	0.240	0.100	0.017	0.009
	10 30	0015	7.1	9.2		490	7.80	188	0.240	0.110	0.015	0.010
	10 30	0022	7.1	9.2		490	7.80	206	0.240	0.100	0.017	0.009
	10 30	0031	7.1	9.0		490	7.80	214	0.250	0.100	0.016	0.010

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/21	13 50	0000	12.7J
72/08/19	14 10	0000	4.0J
72/11/11	10 30	0000	7.7J

J VALUE KNOWN TO BE IN ERROR

STORET RETRIEVAL DATE 74/09/30

555802
43 07 12.0 088 05 42.0
DRAUCHEE LAKE
55 WISCONSIN

11EPALES 2111202
3 0045 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/21	14 05	0000	16.5	9.6	72	385	8.60	187	0.030	0.030	0.015	0.006
	14 05	0015	20.1	9.6		385	8.60	186	0.030	0.040	0.016	0.008
	14 05	0040	6.4	7.2		405	7.80	186	0.300	0.040	0.021	0.008
72/08/19	14 40	0000				400	8.45	168	0.060	0.070	0.015	0.009
	14 40	0004	26.5	8.9		398	8.40	174	0.060	0.060	0.013	0.007
	14 40	0015	22.5	8.0		410	8.30	179	0.060	0.070	0.011	0.007
	14 40	0022	20.2	8.0		410	8.25	179	0.060	0.050	0.011	0.005
	14 40	0027	12.6	5.7		440	7.80	195	0.190	0.050	0.016	0.006
	14 40	0037	7.7	3.4		445	7.50	206	0.400	0.040	0.011	0.006
	14 40	0047	6.6	3.5		450	7.45	196	0.450	0.050	0.014	0.006
	14 40	0057	5.9	4.0		448	7.45	196	0.460	0.040	0.012	0.006
	14 40	0067	5.3	4.0		450	7.50	196	0.470	0.050	0.011	0.006
	14 40	0077	5.1	3.2		450	8.25	198	0.500	0.050	0.014	0.007
72/11/11	10 50	0000			107	490	7.80	206	0.220	0.100	0.015	0.008
	10 50	0004	7.4	8.9		485	7.80	202	0.220	0.100	0.016	0.009
	10 50	0015	7.4	8.7		480	7.80	200	0.210	0.100	0.016	0.009
	10 50	0022	7.4	8.8		480	7.80	199	0.220	0.100	0.017	0.009
	10 50	0035	7.3	8.9		485	7.80	199	0.220	0.110	0.017	0.009
	10 50	0050	7.0	8.8		490	7.80	200	0.220	0.100	0.019	0.009
	10 50	0074	6.6	2.1		495	7.50	194	0.140	0.270	0.033	0.016

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/21	14 05	0000	14.9J
72/08/19	14 40	0000	4.1J
72/11/11	10 50	0000	6.7J

J VALUE KNOWN TO BE IN ERROR

APPENDIX C

TRIBUTARY DATA

STORET RETRIEVAL DATE 74/10/02

[illegible]A1 LS5554A1
43 08 30.0 088 24 30.0
OCONOMOWOC RIVER
55 15 HARTLAND
I/OKAUCHEE LAKE
CO HWY K WING E EDGE STONEBANK
11FRALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/09/23	14 45		0.170	1.050	0.174	0.010	0.043
72/11/03	13 30		0.440	0.970	0.022	0.015	0.032
72/12/09	13 45		0.570	1.380	0.066	0.035	0.063
73/01/06	14 00		0.775	1.320	0.096	0.056	0.070
73/02/11	14 15		0.880	0.880	0.005*	0.024	0.055
73/03/18	09 45		0.880	0.750	0.027	0.035	
73/04/14	14 40		0.800	0.940	0.017	0.021	0.055
73/04/29	14 50		0.740	1.700	0.036	0.011	0.055
73/05/22	13 30		0.240	0.840	0.023	0.007	0.020
73/05/26	13 30		0.750	1.500	0.018	0.019	0.040
73/06/16	14 10		0.540	1.100	0.072	0.033	0.070
73/07/01	10 00		0.520	1.380	0.044	0.011	0.035
73/08/26	14 00		0.420	0.820	0.027	0.013	0.030

* VALUE [illegible] TO [illegible] LESS
[illegible]

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STORET RETRIEVAL DATE 74/10/02

555842
43 06 30.0 088 28 30.0
OCONOMOWOC RIVER
55 15 HARTLAND
O/OKAUCHEE LAKE
US 16 BRDG W OF OKAUCHEE
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/09/23	15	00	0.297	1.100	0.340	0.005K	0.024
72/11/05	13	40	0.099	0.580	0.050	0.003	0.016
72/12/09	14	00	0.250	0.610	0.022	0.002	0.019
73/01/06	15	45	0.290	0.730	0.026	0.003	0.020
73/02/11	14	12	0.340	0.720	0.007	0.005	0.025
73/03/18	10	45	0.430	1.000	0.026	0.007	0.155
73/04/14	13	45	0.350	0.940	0.014	0.005K	0.035
73/04/29	14	15	0.175	1.100	0.016	0.006	0.025
73/05/12	14	30	0.220	0.970	0.026	0.010	0.030
73/05/25	14	50	0.160	1.260	0.052	0.008	0.035
73/06/15	13	25	0.022	1.200	0.048	0.003	0.030
73/07/01	13	10	0.007	1.500	0.060	0.004	0.030
73/08/26			0.013	0.780	0.046	0.008	0.020

K VALUE KNOWN TO BE LESS
THAN INDICATED